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Effect of Strong Base Buffer on Crude Palm Oil Yield

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Abstract

Palm oil and its derivatives are widely used in food and oleo chemical industries, and require high yield of crude palm oil (CPO) to fulfill the demand. In palm oil mills, the yield refers to oil extraction rate (OER) that indicates efficiency to squeeze and collect the crude oil from its palm fruit using steam and separation processes. Breakdown of oil cell bearing of mesocarp by the steam may be enhanced by induction of NaOH while the fiber is being digested. The problem of NaOH corrosivity on the steel material of existing unit operations can be controlled by using sodium silicate to form strong base buffer. In this study, the buffer was sprayed on palm mesocarp fiber after 130°C sterilization for 45 min and digestion. The concentration of NaOH in 1 % sodium silicate and dosage of the buffer were applied at 0.8, 1.0 and 3.0 mol/L, and 1, 3 and 5 L/tonne, respectively. Pressing extraction was subsequently followed to imitate the current methods in the mills. The extracted liquid was further clarified by using a centrifuge and produced three layers: oil, water and non-oily solid (NOS). As an indicator to broken cells, concentration of glucose in a mixture of water and NOS was determined using UV-Vis spectroscopy. Oil after centrifuge (OAC) was also recorded. The mesocarp sample treated with the buffer showed improvement of maximum 6.3 wt% of OER and 53.5 wt% of glucose, respectively, implying improvement of oil release using the NaOH buffer.

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1. Introduction

Oil extracted from palm fruit is the largest source of vegetable oil and derivatives for many food and oleo-chemical products [1]. Over the years, the oil extraction rate (OER) of crude palm oil (CPO) in Malaysia, the second largest exporter, keeps fluctuating around 19% to 20% [2]. Malaysian government through Felda Global Ventures Holdings Berhad particularly aims to achieve 22 wt% OER by 2020 [3].

In palm oil mills, extraction efficiency is usually improved by optimizing sterilization and digestion processes [4]. Generally, the mills involve five basic unit operations: FFB sterilization, FFB stripping, digestion, oil extraction and oil clarification. In the sterilization, the FFB is heated at 40 psig using saturated steam for 70 to 90 minutes to deactivate the lipolytic enzyme activities and to ease separation of fruitlets from bunches [5,6]. The sterilized FFB is then sent to a stripper to separate fruitlets from bunches. The fruitlets are transferred to a digester at temperature ranged between 80°C to 90°C in order to slice mesocarp and breakdown fruitlets into homogeneous mash [7]. Digestion process helps reduce oil viscosity, destroy exocarp and complete the process of breaking down oil bearing cell from the sterilization stage [4,8]. The homogenous mash is then pressed and subsequently clarified to obtain the CPO.

The quality of fresh fruit bunch (FFB) is an important factor that influences OER besides the palm oil mill process [9]. FFB structural composition is comprised of cellulose (44.87%), hemicellulose (26.34%), lignin (14.56%) and others [10]. In order to obtain high yield of CPO, these materials need to be degraded. However, due to their strong chemical bonds, part of them remains even after the pressing [11] and some amount of oil is still trapped in the mesocarp fiber and consequently wasted in pressed fiber [9].

NaOH is capable to breakdown ester bonding between lignin, hemicellulose and cellulose under microwave-assisted conditions thus the cell breakdown and more monomeric sugar released [12]. Using pure NaOH will create stress corrosion cracking to existing unit operations made of steel especially at temperature of hot water (80 – 95°C). [13,14]. Thus, an application of NaOH in the existing milling plants requires buffering system that will equilibrate the substrate at low caustic solution for corrosion prevention [15]. Sodium silicate is a potential buffer normally employed in degreasing and cleaning equipment involved with non-polar, viscous liquid. The objective of this study is to determine the effect of NaOH on CPO yield by looking into extracted oil and glucose content.

2. Materials and Methods

2.1. Materials

Ripe FFBs were collected from a Felda plantation in Kemaman. Dextrose monohydrate, sodium hydroxide and sodium silicate were supplied by Sigma-Aldrich.

2.2. Methods

The process of fruitlet sampling was conducted consistently within one day to avoid deterioration of the fruit. Fruitlets were detached from bunches and further classified into four groups at the same weight (700g). Each group was sterilized by using an autoclave at 130°C for 45 minutes. The sterilized fruitlets were peeled off to separate mesocarp and nuts. Ripeness of oil palm fruitlets varies with respect to their location on the bunch and the region on the fruitlet based on the color of exocarp. Homogenization was carried out by using a mixer to minimize irregularity of sample. 300g of mesocarp fibers were then put in a stainless steel pot and sprayed with the buffer solution that was prepared beforehand. The concentration of NaOH and the dosage of the buffer solution were varied to 0.8, 1.0 and 3.0 molar, and 1, 3, 5 L/tonne, respectively. The mesocarp fibers were placed in 95°C water bath for 45 minutes to undergo digestion process. Hydraulic compressor was used to press and extract the CPO. Next, the extracted CPO was centrifuged at 4000 rpm for 20 minutes. The pure oil layer was separated from the mixture of water and non-oil solid (NOS) and its weight was recorded. The mixture of water and NOS were further tested for glucose analysis by using UV-Vis spectrometer (Agilent Carry 60) at 230 nm. Glucose solution was preliminarily prepared from

dextrose monohydrate at various concentrations to calibrate the spectrometer before the analysis. All tests were replicated at least once to ensure repeatability.

3. Results and Discussions

3.1. Experimental

Fig. 1 shows the average amount of oil collected after the extract being centrifuged for three dosages of sodium silicate at different NaOH loading each: 0 (blank), 0.8, 1.0 and 3.0 molar. Blank sample that was used to each batch of sample only contained water and the digestion in the water bath only involved water at 90°C. OAC content varied among the blank samples due to different quality of samples. The addition of NaOH up to 1 molar improved the collection by 5, 2 and 4 % with respect to the dosages. The addition of 0.8 moles NaOH at 1 L/tonne however shows a lower result of pure oil extracted as compared to the blank sample. Although the run was additionally repeated thrice, the yield was not much different and maximally deviated as shown in error vertical bars on the graph. This might be due to insufficient amount of the buffer and swelling of fiber that made compression slightly less effective and lower oil was obtained. Nevertheless, the improvement was clearly seen and optimum NaOH loading was 1 molar at all dosages which are 54.22%, 53.62% and 54.83%. In addition, the improvement was also evidenced by the increment shown by the trend lines with the best fitness.

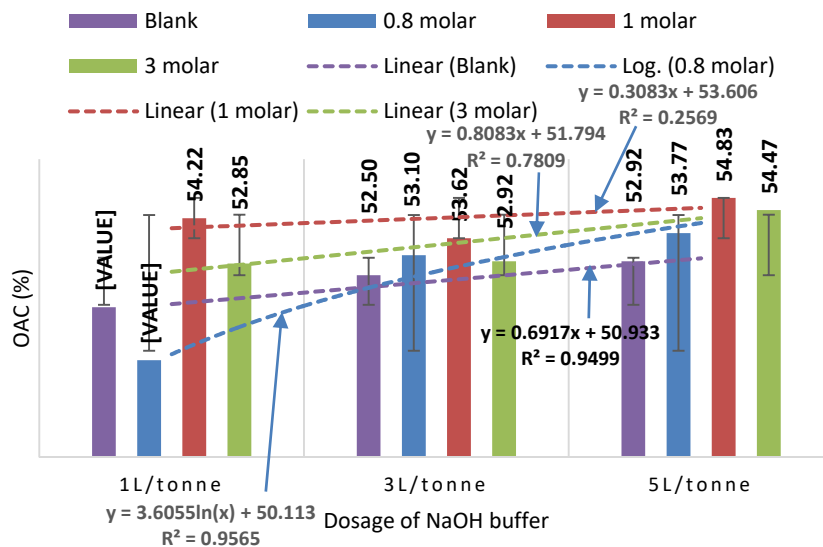


Fig. 1. Graph of average oil after centrifuge (OAC) versus concentration of NaOH and dosage of buffer solution.

According to Iberahim et al. [16], alkaline pre-treatment on the palm oil mesocarp fiber caused the cellulose to swell rather than degrade where its molecular structure changed from crystalline to amorphous. This claim can also be supported by results by Aziz et al. [17]. The researchers concluded that NaOH is able to act as a swelling agent for cellulose. This is supported by Bali et al. [18] who stated that highest cellulose accessibility was observed in diluted NaOH compared to ammonia soaking and lime.

Fig. 2 depicts the response of content of glucose in centrifuged extract against various concentrations of NaOH in the same dosages of buffer solution induced in the digestion of the fiber. In general, NaOH addition to the sodium silicate showed increment of the monomeric sugar by 50%, 10% and 3% in 1, 3 and 5 L/tonne of loadings, respectively. For the 1L/tonne buffer solution, varying the molar concentration of NaOH resulted in a remarkable difference in glucose concentration. Meanwhile, 3 L/tonne and 5 L/tonne dosages of buffer solutions (1.0 and 3.0 molar) show insignificant differences of glucose concentration which are 0.123 mg/mL 0.065 mg/mL respectively. Two possibilities that caused high glucose content at 3 L/tonne and 5 L/tonne dosages in the blank sample. First, as

the abovementioned reason, cellulose bonds might be disrupted by applying buffer solution and thus release of more oil that trapped in the mesocarp fiber as well as increases the yield of CPO. Second, the samples were deteriorated by lignin, cellulose and hemicellulose hydrolysis that took place while the 1L/tonne samples were processed. Hence, the effect of NaOH dosage had least effect.

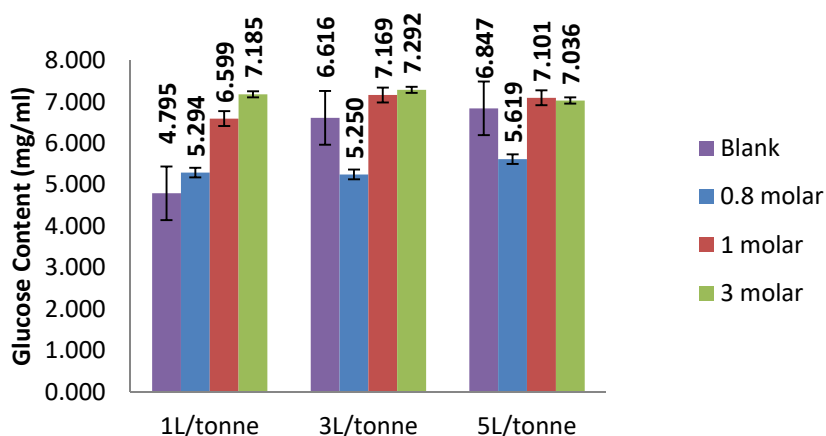


Fig. 2. Graph of concentration of glucose versus. molar concentration of NaOH and dosage of buffer solution.

Hydrolysis reaction of cellulose and hemicellulose produced monomeric sugars including glucose. The release of glucose might be either from cellulose or hemicellulose chains [11]. However, according to Aziz et al. [17], the breakdown of cellulose is only possible by acid hydrolysis and enzymatic saccharification. This can be supported by Chieng et al. [19] who stated that the alkali pre-treatment is only able to dissolve hemicellulose and lignin. These studies found the similar results where NaOH might act as a lignin solvent and removed the protective layers of lignin and hemicellulose [11,20]. Thus, the formation of glucose was probably due to the hydrolysis reaction of hemicellulose. Overall, the buffer solution increased the glucose concentration but the variations of molar concentration of NaOH and dosage of buffer solution had insignificant effects towards the glucose concentration. The digestion process as indicated by Owolarafe et al. [4] induced the rupturing of oil cells and in some cases completely degraded the cellular architecture. The buffer solution probably enhanced the dissolution of hemicellulose so that most of the glucose had been released from the mesocarp.

4. Conclusion

The use of strong base buffer solution on oil palm mesocarp fiber affected the CPO yield. High NaOH loading and dosage of the NaOH buffer resulted in high oil obtained after compression. However, inconsistent results of glucose content were obtained especially at high dosage of the buffer due to different quality of the mesocarp fiber.

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